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TECHNICAL REPORT

A PROTOTYPE MANAGEMENT DECISION SYSTEM FOR PLANNING AND CONTROL

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13. ABSTRACT

The value of timely information as an aid in management decision making has long been recognized. For well structured and predictable problems, conventional batch processing computer techniques and Management Information Systems technology appear to be capable of keeping pace with the rapidly increasing information needs. However, these methods are inadequate for the type of unstructured and poorly defined problems that often confront high level managers - whether they be from the military, industry or government.

It appears that an interactive Management Decision System (MDS), operated and directly controlled by the manager, could provide significant assistance in making the required decisions. This report describes a prototype system that has been implemented to illustrate and evaluate the concept, and to form a basis for subsequent research. Initial experimentation with the system has been very encouraging, and some preliminary results are reported here. A more useful and sophisticated version of the research prototype is now under development.

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It appears that an interactive Management Decision System (MDS), operated and directly controlled by the manager, could provide significant assistance in making the required decisions. This report describes a prototype system that has been implemented to illustrate and evaluate the concept, and to form a basis for subsequent research. Initial experimentation with the system has been very encouraging, and some preliminary results are reported here. A more useful and sophisticated version of the research prototype is now under development.

A PROTOTYPE MANAGEMENT DECISION SYSTEM FOR PLANNING AND CONTROL

1.0 INTRODUCTION

The value of timely information as an aid in management decision making has long been recognized. For well structured and predictable problems, conventional batch processing computer techniques appear to be capable of keeping pace with the rapidly increasing information needs. However, these methods are inadequate for the type of unstructured and poorly defined problems that often confront high level managers - whether they be from the military, industry or government.

It appears that an interactive Management Decision System (MDS), operated and directly controlled by the manager, could provide significant assistance in making the required decisions. A previous report [1] summarized preliminary investigations conducted to define the desirable characteristics of such systems; estimated the potential need, value and applications; and evaluated the present state of the art relative to obtaining the desired features.

This report describes a prototype system that has been implemented in order to illustrate and evaluate the above findings, and to form a basis for subsequent research. A number of low and middle level managers have experimented with the system, and some preliminary results are reported here. Based on the promising results of these efforts, a system capable of performing many of the functions specified in Ref. 1 is being constructed. The design specifications for this system will be described in a separate report [2] to be issued shortly.

Section II discusses the role and value of prototype (demonstration) models in the design of interactive software systems, and thereby provides the motivation and justification for developing this particular prototype system. The system as it now exists is described in Sec. 3.0, and a sample scheduling run is presented in Sec. 4.0. The results and conclusions of the effort thus far are summarized in Sec. 5.0.

2.0 USE OF DEMONSTRATION MODELS IN THE DESIGN OF INTERACTIVE SYSTEMS

2.1 Value of Prototype Models

The value of working prototypes in the design and implementation of on-line interactive systems is receiving increasing recognition [3,4,5]. For a relatively nominal cost, the system designer can build a working model that simulates the operation of the conversational portion of the contemplated final system. (Note that such models are not required for the batch portion of the system since human interaction is not a factor, and sample input and output forms can be manually drawn up to serve the same purpose.) Usually only a small subset of the system capability need be modeled, and the data base organization problems are greatly simplified since only limited artificial data is required for this purpose.

The construction of demonstration models for interactive systems is of value to the system designer in that it forces a formalization of his ideas, and gives him a better feel for the requirements of both the ultimate user and the programmer who will have to implement the design. The programmer also benefits, since he gets a specific and concrete example of exactly what the designer expects from the finished product. Perhaps the greatest beneficiary is the prospective user of the system. It is a form of reference with which he can readily identify, rather than a somewhat abstract description. Experimentation with the model gives him a better feel for the eventual end product and makes it easier to determine and express what he likes, dislikes, wants, does not want, etc. Note also that changes and modifications are almost free at this stage, and there is a great deal of flexibility to make modifications and to experiment with new ideas. Similar experimentation in the later stages of development comes at an extremely high price.

The system described in Secs. 3.0 and 4.0 can be placed in the same category as these demonstration models. It was constructed in a similar manner and for similar experimental purposes. In this application emphasis was on the research and development aspects of the problem, rather than demonstrating a specific system or capability. However, because of the close parallels with demonstration models of proposed operational systems, much of the experience is directly applicable and analogous benefits were derived.

2.2 Determination of Information Requirements

One of the most difficult and critical parts of any interactive system design is to determine the actual future information requirements of the organization to which it is directed - i.e., to find out what answers (decision help) the system will be called upon to provide. It is easy to state that one should study existing systems and methods, and then discuss shortcomings and needs with the appropriate current and potential users. However, this turns out to be easier said than done. Many information system design groups can relate their experiences of circulating questionnaires of this nature and receiving virtually no meaningful response. Individual managers, when approached directly, typically will have little to offer, or they will have requests that are incompatible with what a reasonable system could provide. Constructive answers that are received are often based on the capabilities and structure of the system they are presently using, and rarely take advantage of what an advanced system could provide. One is tempted to conclude that the people to whom the future interactive system will be directed might be the last people to ask for design inputs. However, the foolhardiness of proceeding without direct user involvement has often been demonstrated.

The construction of working models can provide a solution to the above dilemma. Potential system users can be placed "on-line" in an environment much like the final system - without the commitment of major

resources. The act of using a demonstration model can then provide an excellent vehicle for evaluating the requirements of the future system, since it permits the manager to think, act, and function in a manner that closely resembles the future environment. His decisions and requests can then be based on the capabilities of the future system, instead of being confined by familiarity with present operations.

2.3 Aid to System Design

Although the above remarks were centered around the determination of future information requirements of the system, demonstration models can also help to determine such factors as interface language, access devices, response time requirements, and operating environment. This is particularly true of research systems like the one developed here. Before attributing these benefits to demonstration models, however, certain questions must first be answered. For example, is it possible to construct such models quickly and cheaply enough to justify adding their cost and time to that of the overall project? Will the simplified model be realistic and significant enough to present a valid representation of the final system? Will proposed users take the time and effort to become personally involved during this early stage - and remain involved throughout the entire design cycle? The results of this effort thus far appear to reinforce the affirmative answers to these questions given in Refs. 6, 7 and 8.

2.4 General Observations

It was found that most individuals tested thus far took to the prototype system very readily. They learned quickly, and generally enjoyed the experience. More important, they were good at relating the particular model used to the types of problems of interest to them. Useful ideas were often received and new applications frequently suggested.

Based on these experiences, it is concluded that demonstration models can be useful tools in gaining user participation and support during the design phases of interactive systems. In this study users often pointed out deficiencies in the design concept and in the implementation methods and provided a great deal of useful inputs towards correcting them. In general, users can be given the opportunity to become educated in the use of interactive tools and to become intimately involved in the early specification and design of the eventual system - without expending much time or resources. The designer also benefits by obtaining a much better feel for what will be needed, wanted and (more important) used in the future.

3.0 PROTOTYPE SYSTEM DESCRIPTION

3.1 System Description

A prototype interactive Management Decision System for planning has been implemented using the General Electric Company's commercial Mark 2 time-shared system. All programming is in standard time sharing Fortran IV. The system is intended to provide management personnel with the capability to generate limited time-phased scheduling and cost data for proposed or planned products and/or projects. Although applicable for control over the total life cycle, emphasis is oriented towards the design and planning stages. The system provides a convenient technique for the exploration and evaluation of alternative business plans and schedules. By also entering a sales forecast or description of expected revenue, it is possible to estimate such financial data as profit, cash flow, return on investment, etc.

A sample run illustrating the entry and processing of planning data (in CPM format) is given in Sec. 4.0.

The overall system configuration is shown in Fig. 1. Users interface the system in an interactive mode via on-line teletypewriter terminals. There are three basic system modules as follows:

1. Planning and Control Module - This module permits the examination of proposed projects and programs and the costs of implementing them. It also allows for the input, monitoring and updating of data relative to these projects. Provision is included for planning and schedule analysis as well as cost summary and tabulation. The module accepts project descriptions in any of three basic modes:

   a. Critical Path Method (CPM) Network
   b. Gantt Chart (Matrix Format) - Cost as a function of time for each activity
   c. Cost Profile - Cumulative Cost versus Time

The Critical Path Method (CPM) network module permits project analysis by activity and event. For each activity, the user must specify the title, starting and ending event numbers, cost and minimum duration. A simple network is shown in Fig. 2. The standard network representation is given in Fig. 2 and the equivalent tabular description used for program input and output is shown in Table I. Since the starting time for any given activity can be constrained by one or more preceding activities, the actual starting times for many activities may not be known in advance and a network analysis must be performed to determine this information.

The critical CPM notions are those of precedence and float. For example, the engineering and marketing functions in Fig. 2 cannot start until product development has been completed (precedence). Also, since the six months required for marketing is three months less than the sum

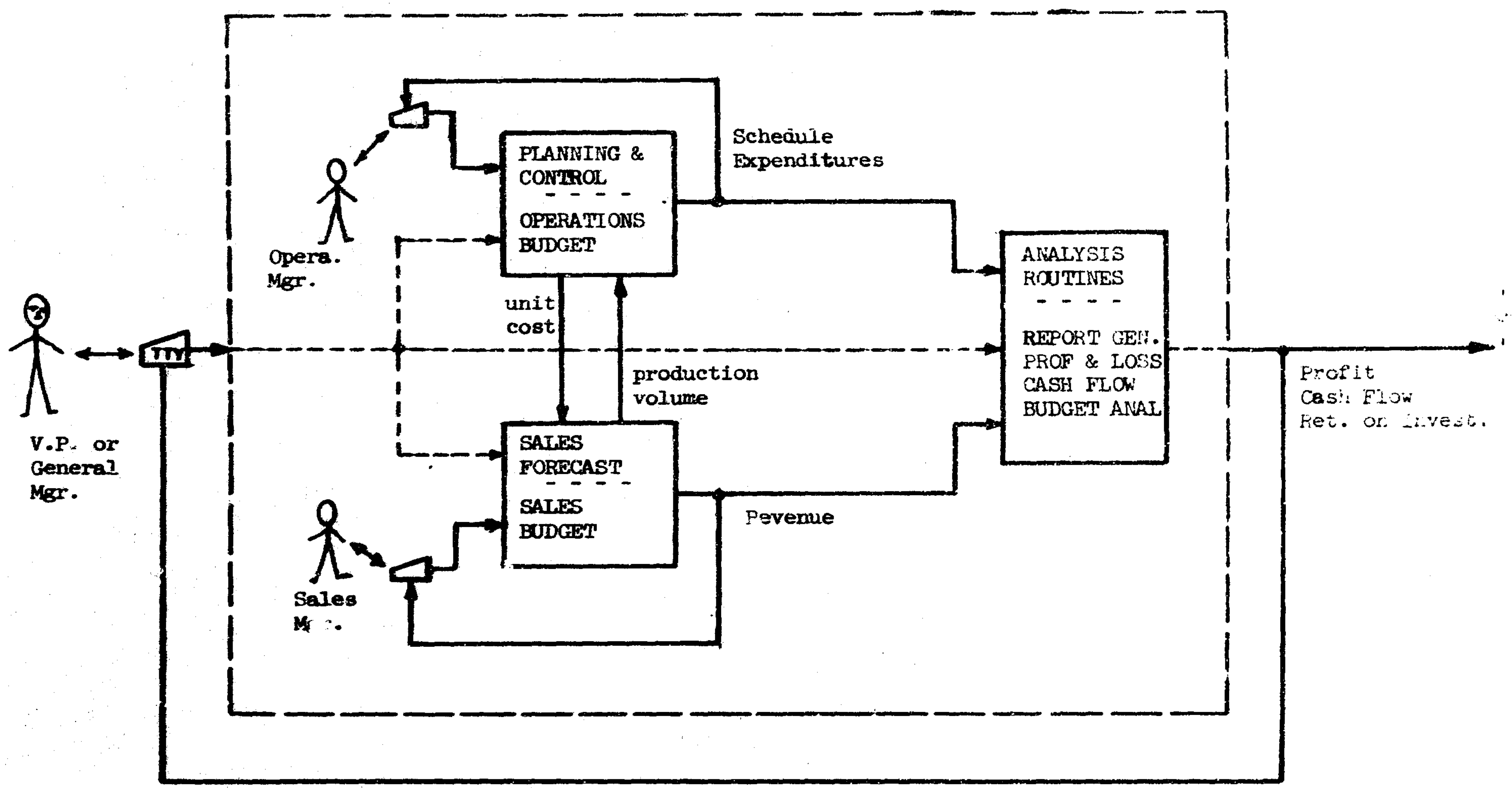

Figure 1

System Configuration

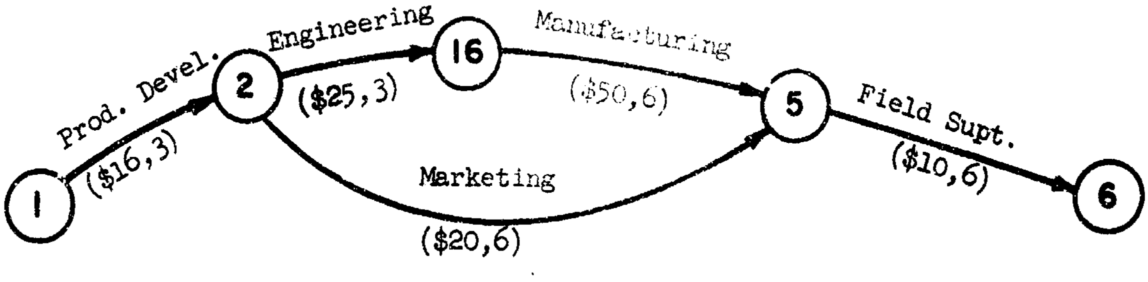

Figure 2
CPM Network Format

Table I - Tabular Description of CPM Network

TITLE	INODE	JNODE	COST	DURATION
PROD. DEVEL.	1	2	16	3
ENGINEERING	2	16	25	3
MANUFACTURING	16	5	50	6
FIELD SUPPORT	5	6	10	6
MARKETING	2	5	20	6

of required engineering and manufacturing times, there is a slack or "float" associated with this activity. Therefore, marketing may be spread over the full nine-month period without delaying project completion. Analysis routines determine such parameters as the permissible range of start and end times for each activity, the critical path and minimum total project duration.

The Gantt Chart (matrix) format can be treated as a special case of the CPM network in which all questions of precedence and float have been resolved. Required inputs for each named activity are reduced to start date, duration, cost and title. The user can input in this form directly, or input the CPM description and let the program solve for the Gantt chart. Figure 3 is a Gantt chart representation of the CPM network shown in Fig. 2. The same data is shown in matrix form as Table II. In this example, the six month marketing function is scheduled to start as early as possible (for competitive purposes) and to end as early as possible (to give manufacturing maximum possible lead time). Note that in the original network description it was obvious that the marketing time span could have been expanded by up to three months (or the start date relaxed by three months) without affecting the total project life-cycle schedule. This information has been lost in the simplified description of Fig. 3 and Table II.

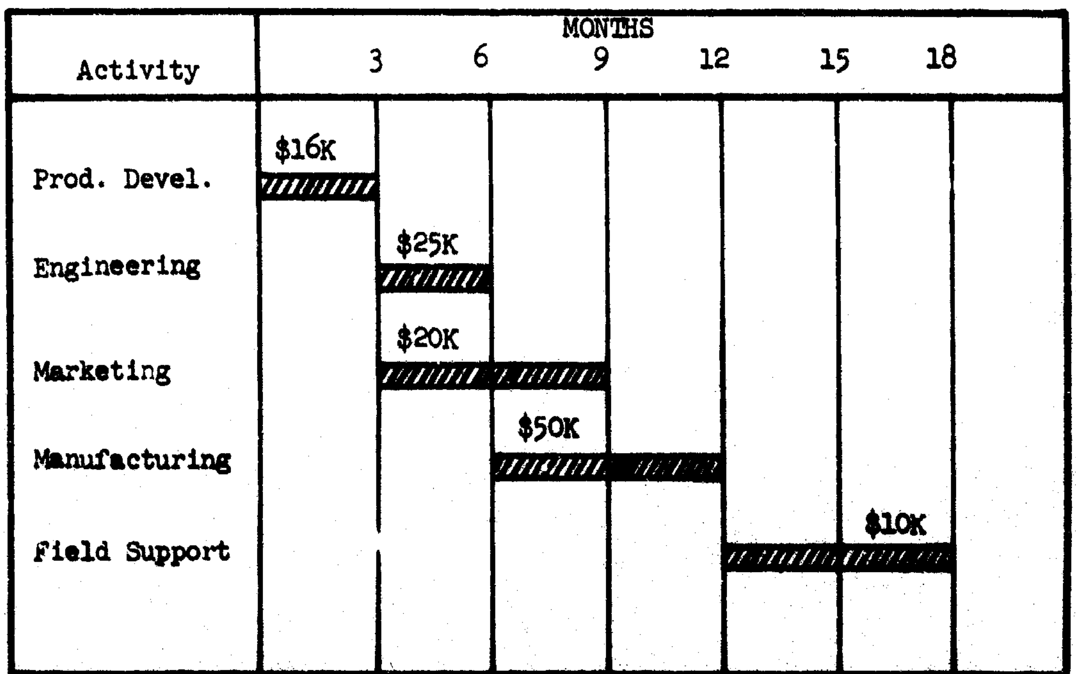

Figure 3 - Gantt Chart Format (Activity Matrix)

Table II - Matrix Format (Cost Distribution)
Representation of Fig. 3

ACTIVITY	START	DURATION (MONTHS)	COST ($K)
PROD. DEVEL.	0	3	16
ENGINEERING	3	3	25
MARKETING	3	6	20
MANUFACTURING	6	6	50
FIELD SUPPORT	12	6	10

The Cost Profile (graphical) format is used in those situations when only total project cost as a function of time is required. These summary costs can be input directly or computed by totaling the costs of all activities described in the matrix format. For the previous example, the cumulative costs are plotted in Fig. 4A, and presented in tabular form in Fig. 4B.

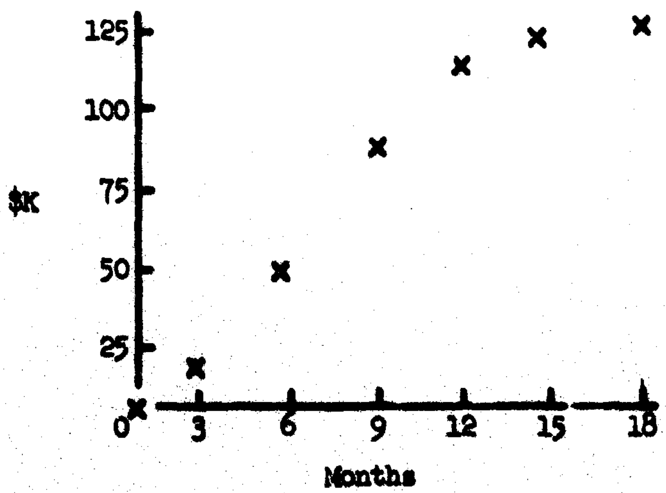

Figure 4A - Graphical Form

Time (Months)	Costs ($K)	Cumulative Costs ($K)
0	0	0
3	16	16
6	35	51
9	35	86
12	25	111
15	5	116
18	5	121

Figure 4B - Tabular Form

Figure 4 - Graphical Format

The three model forms described above can represent successive simplifications or summaries of the same model. The CPM network model would be of interest to a program or manufacturing manager, for example, whereas the tabular summary might be used in compiling a department budget which includes many such programs. Projects may be described in any of the above formats, with successive simplifications performed by the program as desired. This module can be used in a self-contained manner to help derive and/or monitor schedules and budgets, or its outputs may be combined with those of the sales forecast module so that profits and other data can be estimated.

2. Forecasting (Sales Budget) Module - At present, only one type of Sales Forecast format is permitted. This is the "Revenue Profile" which is identical in form to that of the Graphical Input, or Cost Profile, described for the Activity Module. Major interest in this module is in the ability to input a Revenue Estimate that can later be compared with the scheduled costs. It was felt that there was little to be gained in understanding by providing more sophisticated models at this stage of development. Provision has been made for on-line additions, deletions and updates to all revenue files.

3. Analysis and Reporting Module - Part of the function of this module is to provide appropriate summary and reporting (output) capabilities for models built in any of the above formats. In addition, if compatible models exist for both the scheduled costs and the sales forecast, the estimated costs of operations can be matched against projected revenue to determine such financial data as profit profile, discounted cash flow, return on investment, break even point, etc. Some of the available outputs are illustrated in Tables III and IV, and in the plot of Fig. 5.

Table III - Profit Analysis Data

EXPECTED LIFE CYCLE PROFIT	= $11,805
EXPECTED LIFE CYCLE % PROFIT	= 34.5%
PROFIT DATA REFLECTS AN ANNUAL COST OF MONEY	= 9.5%
RETURN ON INVESTMENT	= 13%[1]

[1] Net return on investment is that value of r such that $\sum_{i=0}^{n} \frac{r_i}{(1+r)^i} = 0$.

r_i = revenue at time i (can be + or -)

Table IV - Profit Tabulation

Time Period (Quarter)	Expected Profit ($)	Cumulative Profit ($)
1	-3000	-3000
2	-2000	-5000
3	-1500	-6500
4	4000	-2500
5	5000	2500
6	4000	6500
7	4400	10900
8	905	11805

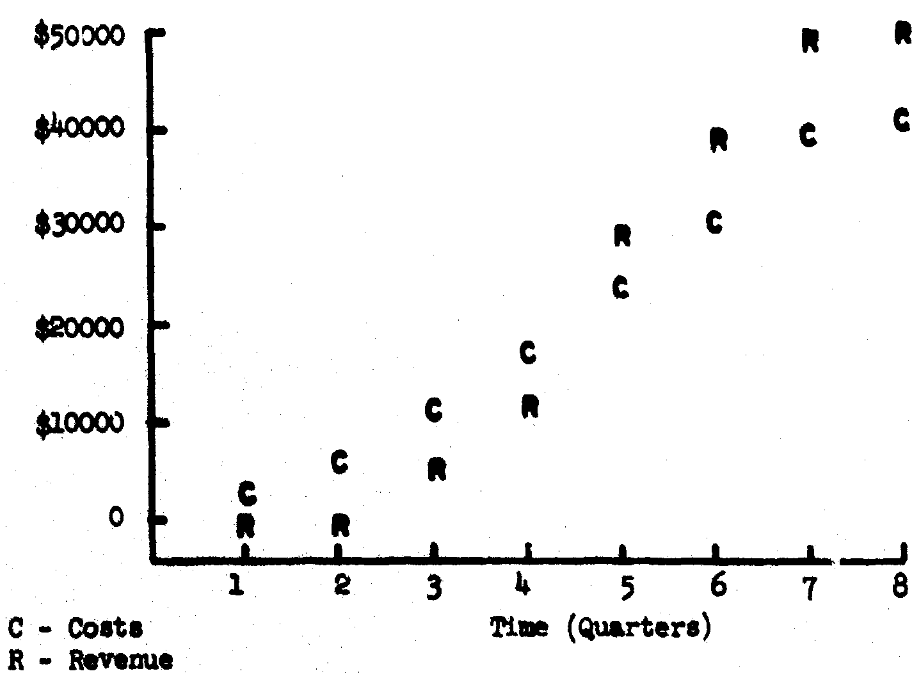

Figure 5 - Costs vs. Revenue

3.2 System Features

1. Fully Interactive - The system is fully interactive and designed for use by a manager with little or no prior computer experience or preparation. Input requests are self-explanatory, data is entered in free form, and instructions are provided as required.

2. Hierarchy of Model Types - The planning module permits a hierarchy of sophistication of model description, depending on the users' needs and interests. It is possible, for example, to use the CPM network for detailed planning and control, a Gantt chart representation for budgeting purposes, and a simple cumulative cost compilation for summary comparisons.

3. Hierarchy of Organizational Descriptions - In addition to the hierarchy of model types described above, it would be desirable to be able to represent an organizational hierarchy - for example, to permit high level control over total costs, and detailed project level control over specific activities. This capability has been provided for illustrative purposes, for one level of hierarchical structure, with the CPM and Gantt chart formats of activity models. Listed activities may be grouped into any arbitrary number of classifications. Provision has been made to name the classifications, to assign activities to classes as desired, and to compute cost subtotals by classification. The classification structure can represent activity groupings, organizational level, labor category, etc. If no classifications are assigned, it is assumed that there is one (unnamed) classification to which all activities belong.

4. Hierarchy of Users - Each user can select a model type that reflects his level in the organization hierarchy. This level will also be a factor in the use and selection of system modules and options. A production manager, for example, might build a detailed CPM production schedule using the planning module. On the other hand, a company Vice-President interested in expected profit or cash flow might use the analysis module to combine the cumulative costs for a CPM model with a summary of the marketing manager's sales forecast.

5. Modular Construction - The system is composed of self-contained program modules and routines. This permits a great deal of flexibility in system use and operation. In addition, the modification of subroutines, the substitution of different computation algorithms, and the addition of new program modules is greatly simplified.

6. Input-output Formats - Input is entered in free form, usually by responding to a request from the terminal. For simplicity, output formats are fixed and predetermined, although there is flexibility in selecting the desired reports and report forms. At the user's option, most data files and computation results may be output in tabular and/or graphical (printer-plot) form.

3.3 Applications and Typical Users

Since we are discussing a fairly comprehensive system, useful to many people for many diverse purposes, it would not be particularly enlightening to attempt an enumeration of possible applications. Instead, several typical uses are described below in an attempt to indicate the diversity of applications and the kind of decision help that could be rendered from an operational system of the type described here.

1. Production Manager (Program Manager) - This user would be primarily concerned with the planning and control module, and would use that module in great depth. He may use the output of other modules - for example, to obtain estimates of sales (required production volume) from the forecasting module - but this usage would be secondary. In the proposal or planning stages of projects he might use a CPM model to establish schedules, estimate costs, prepare budgets and resource estimates, or explore alternative implementation procedures. Later, actual expenditures and accomplishments can be entered and the system used to generate status reports, predict trends, and update the schedules and budgets. Note that at any point in time the process of changing and updating can be interpreted as either future planning or present monitoring and control.

2. Contract Monitor and Performance Evaluation - A government or other funding organization could utilize the planning and control module to monitor and evaluate the performance of contractors. The initial schedule could be supplied by the vendor or entered directly from the schedule required on most government contracts. In addition to monitoring performance, the model could be used to examine the effects of potential problems and to analyze the implications of contemplated changes in contract scope or definition.

3. Manager of Marketing - This user is concerned primarily with the forecasting module, although he may use cost and other production data from the operations module. He is interested in setting sales quotas, composing budgets, and making forecasts for various possible selling prices, production schedules and profit profiles.

4. General Manager - Assuming that the above production and marketing managers had built models as described, a higher-level manager might want to examine summary outputs of their models for several purposes. He might, for example, superimpose the cost outputs of all existing planning models to estimate the total costs of doing business, the required cash resources, etc. Alternatively, he might want to superimpose the sales forecasts to get estimates of total expected revenue, or he might compare expected costs with the sales predictions in order to obtain a pro-forma profit statement. This would be useful in making decisions relative to product selection and product mix.

5. <u>Proposal Evaluation</u> - A military or other government agency might use such a system to model and compare competitive bids as a tool in contractor selection. The capability to examine, superimpose and manipulate various proposed schedules (planning and scheduling module) and funding requests (budgeting module) could be extremely useful in comparing the costs and potential value of alternative approaches or proposals.

4.0 SAMPLE SCHEDULING RUN WITH PROTOTYPE PLANNING SYSTEM

4.1 Sample Problem

As an example of a typical scheduling problem, consider the design and development of a new gas storage field for a major utility company. This project could represent capital expenditures ranging in the millions of dollars. The activities that take place from conception to implementation must therefore be scheduled for optimum utilization of personnel and economy of resources.

Before the actual construction work is started, geological, engineering and cost evaluations must be made. Next, land must be acquired at the field location and at all necessary right-of-way and pipeline and compressor station areas. Finally, the gathering system and compressors must be constructed and the wells drilled.

The overall flow of activities for such a hypothetical project is represented by the Critical Path Method (CPM) diagram of Fig. 6. The tasks are divided into three categories or classifications: evaluation, land acquisition, and installation. Since there is a separate responsibility for each of these areas, the activities are grouped by classification as shown in Table V, and separate cost subtotals will be provided for each classification category.

The sample run to be described represents the initial step in the analysis and optimization of the schedule shown in Fig. 6. The objective was to input and examine the Critical Path Method description of the contemplated project schedule. This consisted of a CPM network analysis and solution, and the derivation of various summary reports, graphs and charts describing the solution obtained.

4.2 Sample Run Description

One way to organize the data for initial program input is to draw a diagram like that of Fig. 6. Frequently, this initial diagram will be a simple free-hand sketch with the complete activity descriptions and classification assignments entered directly on the diagram. Note that neither the dates (relative to time zero) for performing each task nor the critical path is obvious at this stage of the analysis.

The sample run (Figs. 7a to 7g) should be relatively self-explanatory and will not be discussed in detail. It is of interest, however, to summarize the overall program flow with reference to the figures. (Note that underlined items represent user inputs or responses.) After the standard system sign-in procedure, the executive program (LCEXEC) is used (Fig. 7a) to call the file building module for entering a new CPM activity file in the file previously reserved as TEST1. After all data has been entered, control is switched to the file summary and modification program (Fig. 7b). This program is used to display the stored file data and to correct the previous input errors and omissions.

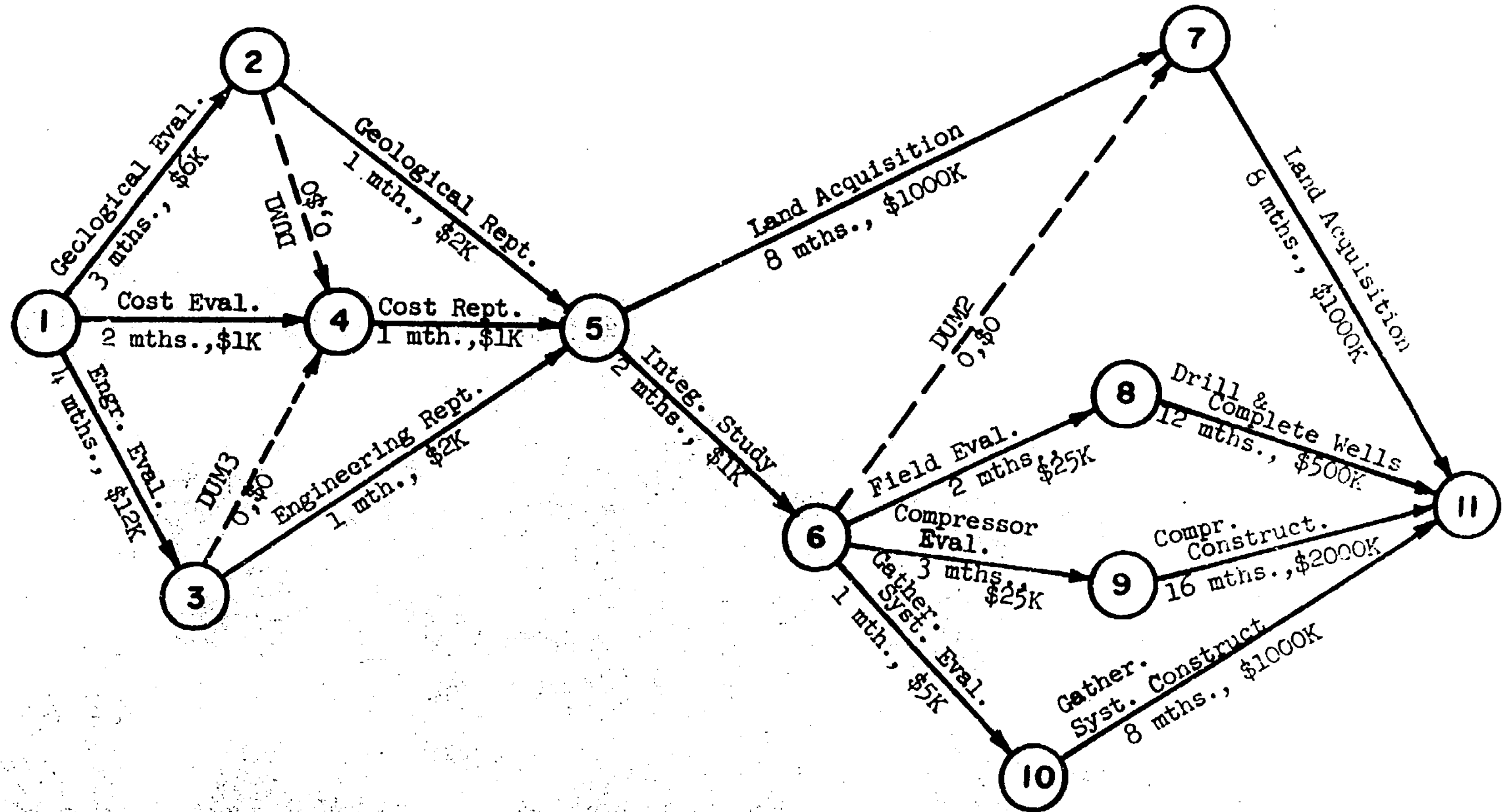

Figure 6

Gas Storage Field Design

Table V

Classification Groupings for Sample Problem

Class No.	Classification
1	Evaluation (EVAL)
2	Acquisition (ACQU)
3	Installation (INST)

Task Id.	Class	Task
GEVL	1	Geological Evaluation
EEVL	1	Engineering Evaluation
CEVL	1	Cost Evaluation
GRPT	1	Geological Report
ERPT	1	Engineering Report
CRPT	1	Cost Report
DUM1	1	Dummy Task No. 1
LACQ	2	Land Acquisition
LEGL	2	Final Legal Work
DUM2	2	Dummy Task No. 2
ISTY	3	Integration Study
FEVL	3	Field Evaluation
D&C	3	Drilling and Completion of Wells
CEVL	3	Compressor Evaluation
CCON	3	Compressor Construction
GSEV	3	Gathering System Evaluation
GSCN	3	Gathering System Construction
DUM3	3	Dummy Task No. 3

The CPM analysis modules are illustrated in Fig. 7c. CPMONE checks the network for such logical inconsistencies as loops, multiple starts, parallel activities and multiple end events. If the network is logically correct, CPMTWO then carries out the network analysis. In addition to the tabular output of CPMTWO, it is often interesting to examine the data in bar chart form as shown in Fig. 7d. If all activities started as early as possible, and were completed as early as possible, the project would proceed as shown by the *'s. The +'s indicate the available slack, if any, for each activity. Hence, slippage over these dates will not affect the critical path. The solution is then stored in Gantt Chart (standard) form as file TEST2.

The example of the report module illustrated in Fig. 7e shows the output of the standard format data of TEST2. For financial purposes, all cost data will be expressed in terms of the present value (time = 0) of money. In this example, a 12% annual rate is assumed.

Finally, the cumulative costs for all activities are computed as a function of time and plotted as Fig. 7f. These results are shown in tabular form in Fig. 7g. The costs are also saved in this graphical form as TEST3 in case the need to access or manipulate the results arises.

The emphasis on this run was in storing and analyzing a particular contemplated CPM schedule. Future runs can now recall any of the stored descriptions (CPM, cost distribution chart, or graphical) for on-line modification, update and/or report generation.

```
MKII 011-017   09:19 EDT   15 OCT 70
USER NO.--[redacted]
PROJECT ID--
SYSTEM--FORTRAN
NEW OR OLD--OLD LCEXEC
READY
RUN
```

SYSTEM SIGN-ON, CALL EXEC PROG.

```
                    - - - - - - - - - -

LCEXEC       0920 EDT     10/15/70


L. C. EXECUTIVE PROGRAM

WORK ON A FILE (FILE) OR GENERATE REPORTS(GEN)--?FILE

ACTIVITY (A) OR SALES FORECAST (SF) FILE--?A

MULTIPLE ACTIVITY FILES--?NO

ACTIVITY FILE NAME = ?TEST1

FILE IS CPM(C), STD(S), OR GRAPH(G)--?C

OLD OR NEW FILE--?NEW

CHAINING TO FILE BUILDING MODULE
                    - - - - - - - - - -
ENTER NUMBER OF ACTIVITIES IN FILE,NO. OF CLASSIFICATIONS?17,3

ENTER CLASSIFICATION NUMBERS AND CLASSIFICATION NAMES
 ?1 EVAL
? 2 ACQU
? 3 INST

ENTER ACTIVITY RECORDS WITH FIELDS IN FOLLOWING SEQUENCE:
INODE,JNODE,DURATION,COST,CLASSIF.,TITLE:
 ?1 2 3 4 1 DEVL
?1 3 4 10 1 EEVL
?1 4 2 1 1 CEVL
?[illegible]
?[illegible]
?[illegible]
?1 4 0 0 1 DUM1
?5,7,5,1000,2,LACO
?[illegible] LEM
?6 7 0 0 2 DUM2
?[illegible]
?6, 8, 2, 25, 3, DACW
?6 7 3 25 3 CEVL
?4 10 1 5 3 OSEV
?8 11 12 500 3 DAC
?9 11 16 2000 3 CCON
?10 11 8 1000 3 OSC
```

CALL ROUTINE FOR BUILDING CPM ACTIVITY FILE

NOTE DIFFERENT PERMISSIBLE DATA ENTRY FORMATS

BUILD CPM FILE

```
LIFE-CYCLE FILE-SUMMARY AND MODIFICATION PROGRAM DESIRED? (Y OR N)
 ?Y
```

Figure 7a
Build New CPM File

```
YOU ARE NOW BEING SWITCHED TO THE LIFE-CYCLE FILE
-SUMMARY AND MODIFICATION PROGRAM

ACTIVITY FILE SUMMARY REQUIRED? - (Y OR N)?Y
```

STORED CPM FILE "TEST1"

FILE SUMMARY - TEST1

ACTIVITY CLASSIFICATIONS

RECORD NUMBER	CLASSIFICATION NUMBER	CLASSIFICATION
1	1	EVAL
2	2	ACQU
3	3	INST

REC-NO.	CLASS	ACTIVITY	I	J	DURATION	COST
4	1	GEVL	1	2	3	6
5	1	EEVL	1	3	4	12
6	1	CEVL	1	4	2	1
7	1	GRPT	2	5	1	2
8	1	ERPT	3	5	1	2
FARMS 9	1	CRPT	4	5	1	1
X → 10	1	DUM1	~~1~~ → 3	4	0	0
11	2	LACQ	5	7	8	1000
12	2	LEGL	7	11	3	25
13	2	DUM2	6	7	0	0
14	3	ISTY	5	6	2	1
X → 15	3	DACQ → FEVL	6	8	2	25
16	3	CEVL	6	9	3	25
17	3	ØSEV	6	10	1	5
18	3	D&C	8	11	12	500
19	3	CCON	9	11	16	2000
20	3	GSC	10	11	8	1000

```
FILE TRUNCATION OR SELECTIVE DELETION REQUIRED?-(Y OR N)?N

ACTIVITY FILE MODIFICATION REQUIRED? -(Y OR N)?Y

ENTER NO. OF MODIFICATIONS.  NO. OF ADDITIONS? 2, 1

ENTER MODIFICATION RECORDS IN FOLLOWING FORMAT:
REC-NO.. INODE. JNODE.CLASSIF-NO.. DURATION. COST. TITLE
 ?10 3 4 1 00 DUM1 DELETED
10 3 4 1 0 0 DUM1
?15 6 8 3 2 25 FEVL
```

CORRECT INPUT ERRORS

```
ENTER ADDITIONAL RECORDS WITH FIELDS IN FOLLOWING SEQ
INODE.JNODE.DURATION.COST.CLASSIF-NO..TITLE
 ?2 4 0 0 1 DUM3
```

ADD EXTRA DUMMY ACTIVITY

```
ACTIVITY FILE SUMMARY REQUIRED? - (YPOR N)?N

FILE TRUNCATION OR SELECTIVE DELETION REQUIRED?-(Y OR N)?N

ACTIVITY FILE MODIFICATION REQUIRED? -(Y OR N)?N

ACTIVITY FILE SUMMARY REQUIRED? - (Y OR N)?N

DO YOU WISH TO PROCESS THIS FILE THROUGH THE CPM MODEL? -(Y OR N)?Y
```

Figure 7b - Summarize and Modify Stored File

YOU ARE BEING SWITCHED TO THE 'CPM' MODULE

THIS IS CPMONE FOR CHECKING LOGIC OF CPM NETWORK

ACTIVITY FILE GENERIC(G), OR UNIT DATA(U)??U

CHECK LOGICAL VALIDITY OF CPM NETWORK

TOTAL PROJECT CALCULATED COST = $ 4605

DISTRIBUTION OF LIFE CYCLE COSTS BY CLASSIFICATION:

CLASSIFICATION 1 - EVAL = $ 24
CLASSIFICATION 2 - ACQU = $ 1025
CLASSIFICATION 3 - INST = $ 3556

START EVENT = 1; END EVENT = 11

NO LOGIC OR CONCEPT ERRORS IN NETWORK DESCRIPTION
'CPMTWO' IS BEING CALLED TO FIND CRIT PATH AND ANALYZE THE NETWORK

CPM ANALYSIS COMPLETE.

CAN SORT OUTPUT ON ANY OF FOLLOWING COLUMNS:

I	J	DUR	EAR ST	EAR FIN	LATE ST	L FIN	FLOAT	LEV	COST
1	2	3	4	5	6	7	8	9	10

WHAT COLUMN FOR SORT--?4

CPM ANALYSIS AND SORT

MIN TOTAL DURATION = 26; TOTAL COST = 4605

CRIT	I	J	DUR	EAR ST	EAR FIN	LATE ST	L FIN	FLOAT	LEV	COST
	1	2	3	0	3	1	4	1	1	6
*	1	3	4	0	4	0	4	0	1	12
	1	4	2	0	2	2	4	2	1	1
	2	5	1	3	4	4	5	1	2	8
	2	4	0	3	3	4	4	1	2	0
*	3	5	1	4	5	4	5	0	2	2
*	4	5	1	4	5	4	5	0	3	1
*	3	4	0	4	4	4	4	0	2	0
	5	7	8	5	13	15	23	10	4	1000
*	5	6	2	5	7		7	0	4	1
	6	7	0	7	7		23	16	5	0
	6	8	2	7	9	12	14	5	5	25
*	6	9	3	7	10	7	10	0	5	25
	6	10	1	7	8	17	18	10	5	5
	10	11	8	8	16	18	26	10	6	1000
	8	11	12	9	21	14	26	5	6	500
*	9	11	16	10	26	10	26	0	6	2000
	7	11	3	13	16	23	26	10	6	25

PROCESSING COMPLETE.

Figure 7c
Analyze CPM Network

```
BAR-CHART PRINTOUT OF 'CPM' RESULTS DESIRED?-(Y OR N)
?Y

                              BAR-CHART - CPM ACTIVITIES

                            PRODUCT DESCRIPTION - TEST1

                              BAR-DATA  =  EAR ST + DURATION
                                FLOAT   =  '+'

       I :   1   1   1   2   2   3   4   3   5   5   6   6   6   6  10   8   9   7

       J :   2   3   4   5   4   5   5   4   7   6   7   8   9  10  11  11  11  11
----------------------------------------------------------------------------------------------

        0.   *   *   *
        1.   *   *   *
        2.   *   *   *
        3.   *   *   +   *   *
        4.   +   *   +   *   +   *   *   *
        5.               +       *   *       *   *
        6.                                   *   *
        7.                                   *   *   *   *   *   *
        8.                                   *       +   *   *   *   *
T       9.                                   *       +   *   *   +   *   *
I      10.                                   *       +   +   *   +   *   *   *
M      11.                                   *       +   +       +   *   *   *
E      12.                                   *       +   +       +   *   *   *
       13.                                   *       +   +       +   *   *   *   *
P      14.                                   +       +   +       +   *   *   *   *
E      15.                                   +       +           +   *   *   *   *
R      16.                                   +       +           +   *   *   *   *
I      17.                                   +       +           +   +   *   *   +
O      18.                                   +       +           +   +   *   *   +
D      19.                                   +       +               +   *   *   +
       20.                                   +       +               +   *   *   +
       21.                                   +       +               +   *   *   +
       22.                                   +       +               +   +   *   +
       23.                                   +       +               +   +   *   +
       24.                                                           +   +   *   +
       25.                                                           +   +   *   +
       26.                                                           +   +   *   +

DO YOU WANT ANOTHER SORT? - REPLY(YES OR NO)?NO

DO YOU WANT TO PRESERVE RESULTS IN STD FORM--?YES

FILE WILL BE SORTED BY EARLIEST START

ENTER FILENAME OF RESIRVED OUTPUT FILE:?TEST2
```

SAVE PROCESSED FILE

Figure 7d
Bar Chart Representation of Network Solution

```
BRANCH TO EXEC(EXEC) OR REPORT(REPT).MODULE--?REPT

THIS IS THE REPORT PROGRAM FOR PROCESSING ANY ACTIV-
ITY FILE OR ANY S.F. FILE -- OR BOTH

FILE FORMAT IS CPM(C), STD(X), OR GRAPH(G)--?X

DOLLAR FIGURES TO BE PROCESSED IN TERMS OF PRESENT VALUE--?YES

ENTER % VALUE OF MONEY, NO TIME UNITS PER YEAR?12, 12
```

OUTPUT COSTS WILL REFLECT A 12% RATE FROM TIME 0.

```
IS ACTIVITY FILE REQUESTED? -(Y FOR N)?Y

ENTER NAME OF DESIRED ACTIVITY FILE?TEST2

SALES-FORECAST FILE DESIRED? (Y OR N)?N

ACTIVITY FILE DATA IN PERCENT OR UNITS? -(P OR U)?U

TOTAL PROJECT CALCULATED COST = $        4251

DISTRIBUTION OF LIFE CYCLE COSTS BY CLASSIFICATION:

     CLASSIFICATION  1 - EVAL =  $    21
     CLASSIFICATION  2 - ACQU =  $   975
     CLASSIFICATION  3 - INST =  $  3255
```

EXAMINE STORED STD (MATRIX) FILE "TEST2"

```
COST DISTRIBUTION CHART, IN UNITS, DESIRED?- ( Y OR N)?Y

DISTRIBUTION OF LIFE CYCLE COSTS AND ACTIVITY DURATIONS

                    LIFE CYCLE
                  PLANNING MODEL

          PRODUCT DESCRIPTION - TEST2
```

CLASS	ACTIVITY	START	DURATION	COST
1	GEVL	0	3	6
1	EEVL	0	4	12
1	CEVL	0	2	1
1	GRPT	3	1	1
1	DUM3	3	0	0
1	ERPT	4	1	1
1	CRPT	4	1	0
1	DUM1	4	0	0
2	LACQ	5	8	953
3	ISTY	5	2	0
2	DUM2	7	0	0
3	FEVL	7	2	23
3	CEVL	7	3	23
3	OSEV	7	1	4
3	BSC	8	8	927
3	DAC	9	12	459
3	CCON	10	16	1819
2	LEGL	13	3	22

"STANDARD" (MATRIX) FILE

Figure 7e
Examine Standard (Matrix) Representation of Solution

ENTER LIFE-CYCLE TIME UNITS -I.E.WEEKS,MONTHS,YEARS, OR, QUARTERS:
?MONTHS

TOTAL LIFE CYCLE TIME = 26 MONTHS

TOTAL LIFE-CYCLE DIRECT COST = $ 4251

GRAPHICAL OUTPUT DESIRED?-(Y OR N)?Y

TOTAL LIFE CYCLE COST = $ 4251

TOTAL LIFE-CYCLE REVENUE = $ 0

GRAPH SCALE: 1 POSITION = $ 85.02

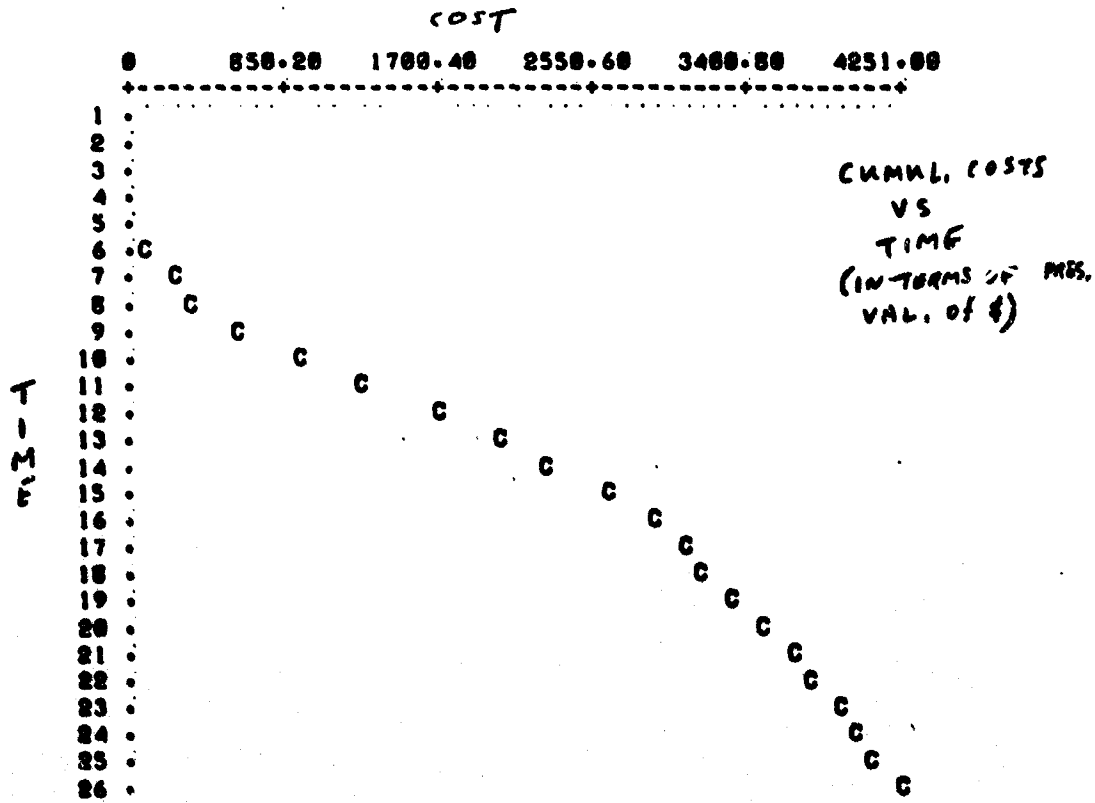

Figure 7f
Graphical Output of Estimated Cost

TABULAR REPORT DESIRED FOR ACTIVITY GRAPH DATA? (Y OR N)?Y

CUMULATIVE COST BY SPECIFIC PERIOD DESIRED?-(Y OR N)?Y

ENTER ACCUMULATION PERIOD?3

ACTIVITY FILE PLOT DATA - TEST2

TIME	COST	CUM COST	PERIOD TOTALS
1	6	6	
2	6	11	
3	5	16	16
4	4	20	
5	1	21	
6	119	140	124
7	119	259	
8	142	402	
9	254	656	516
10	281	937	
11	387	1324	
12	387	1711	1055
13	387	2097	
14	275	2373	
15	275	2648	937
16	275	2923	
17	152	3075	
18	152	3227	579
19	152	3379	
20	152	3531	
21	152	3683	456
22	114	3796	
23	114	3910	
24	114	4024	341
25	114	4137	
26	114	4251	

DO YOU WISH TO SAVE ACTIVITY GRAPH DATA (COST VS TIME)
AS A SPECIFIC FILE?-(Y OR N)?Y

SAVE ABOVE TABLE (GRAPH) DATA AS "TEST3"

ENTER NAME OF DESIRED GRAPH FILE: ?TEST3

END OF LIFE-CYCLE ANALYSIS
RETURNING TO LIFE-CYCLE EXECUTIVE MODULE

Figure 7g
Table Representation of Graph

5.0 SUMMARY AND CONCLUSIONS

The prototype system developed permits preliminary project scheduling and costing using Critical Path Method (CPM) or other planning models; the entry of sales forecast or expected revenue profiles; and the comparison of the resultant cost and revenue estimates in order to predict profit potential, return on investment, cash flow, discounted cash flow and other financial data. The model provides a helpful tool for the planning of single projects or programs. It is also useful in demonstrating the operation of interactive management systems, particularly to those without previous experience with interactive computation. The major use of the system in this study, however, was as an experimental vehicle to develop techniques and evaluate the feasibility of providing managers with on-line access to computer-based planning, modeling and other decision making tools.

This section summarizes the more general preliminary conclusions reached after limited research and experimentation with the prototype system (re: Secs. 3.0 and 4.0). Detailed results relative to implementation such as user language, procedures, system content, etc. will be incorporated into the final system design described in Ref. 2.

In general, the system was found to be easy to learn and use, and the fast response and absence of intermediaries between managers and the computer is felt to be a promising combination. One problem noted was that the slow output speeds of the teletypewriter terminals quickly became tedious as user efficiency increased. Hence, although it is desirable to have built-in dictionaries, tutorials, and other user guides so that learning and use of manuals is minimized, users should not be forced to sit at a console and watch while unneeded help or instructions are being printed. The moral is: provide help when, and only when, needed. This implies that required dialog for the experienced user must be minimized and high speed output devices should be utilized wherever possible. The possible substitution of alphanumeric cathode ray tube (CRT) display consoles for the teletypewriter is being given strong consideration.

Based on the above experiences, the following general conclusions appear valid:

1. The Concept of Interactive Planning Models Appears Promising - The study results are very encouraging and further development work is warranted. Initial indications from the prototype system are that managers find it easy to identify with and use this type of program, and that it can be useful in planning, scheduling and other decision making. The capability for large scale implementation of such models is, or will shortly be, readily available. Required application programs and data files are already being developed in many areas.

2. Ultimately, Planning Models Should Be Operated as Integral Parts of Large Management Decision Systems - The real potential power of such tools lies in their ability to interact with and complement other parts of a total Management Information System. This can provide a substantial increase in the power and value of the Information System at a comparatively nominal incremental cost. Planning models, for example, must interact with sales forecast models, financial models, business simulation models, and large banks of data.

3. State of the Art Shortcomings are Diminishing - There are still some serious shortcomings in available hardware and software that will slow the development of the desired interactive capability. At present, for example, available input/output terminals suffer from such problems as being too slow, too expensive, lacking visual (CRT) and graphical display capability, not having hard copy output, etc. In addition, most present computer systems do not yet provide adequate time-shared software. There are no (except possibly unpublished proprietary) interactive file management systems of adequate capability - let alone interactive Management Decision Systems. However, all of these areas are receiving much attention and the difficulties are diminishing rapidly. Hence it is not expected that hardware and software shortcomings will present major barriers to the successful implementation of interactive systems.

4. Hierarchical Models and Data Bases are Required - The programs and data bases must be capable of functioning with a hierarchy of levels - each representing a processed subset of information from the next lower level. To some extent this hierarchy will parallel that of the business organization. A project manager, for example, might be interested in detailed cost and schedule data relative to his project, while his supervisor may only be interested in comparing and combining the project summary totals with those of several other projects. The levels of the hierarchy are closely interrelated and one of the key system requirements is the capability to move freely between and among the various hierarchical levels.

5. Information Requirements are Difficult to Define - The most difficult part of system design may be in the determination of the future information and decision requirements of the organization. Few methods exist for determining the information requirements in specific situations, or for identifying the general requirements of a wide variety of managers. There are many reasons why this problem exists. Almost by definition, managers have learned to function in their present environment and with presently available information sources. Consequently, they are often not anxious to explore ways to change that environment, and are not particularly aware of missing information or the value of new or more responsive sources or forms of information.

Frequently, managers are not as enthusiastic about the potential of on-line systems as one would anticipate. Those who have been involved in similar problems have often been "burnt" by the promises of computer hardware and (especially) software people who later proved to be unable to meet promised costs, schedules, or design specifications. As a result,

managers are becoming increasingly wary when the subject of new computer-based systems is brought up. This problem is compounded by the unfamiliarity of many managers with the potential of the information field, and by difficulty of putting a dollar value on the benefits of obtaining better or more timely results. (Note that there is no corresponding difficulty in recognizing the large capital investment needed to build and operate such systems.)

Even if the above barriers have been overcome, the problem of determining the future information requirements of the organization is still significant. Knowledge of the present environment, and the capabilities and shortcomings of the present system and procedures, may present a very narrow and limited viewpoint relative to the potential of a new system.

6. Early Demonstration Models Can Provide Significant Design Help - The use of demonstration models as was done here could alleviate many early design and communication problems by giving future users a chance to work and operate in an environment that closely resembles the proposed future system. This could be done before any significant design commitments are made, and hence permit a great deal of experimentation and user involvement during the early phases of system design.

6.0 REFERENCES

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